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SUSTAINABILITY AND CARBON FOOTPRINT EVALUATION AT UNIVERSITY: CASE STUDY OF VILNIUS TECH

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Abstract. Because of a societal push towards sustainability a problem emerges of adapting the concept to different sectors of the economy and society. The differing complexities of different fields and social structures make it difficult to create a universal sustainability strategy. Higher education institutions (HEIs) consist of a broad range of people, working in various fields of industry, making it an appropriate cross-section of the nation. Adapting sustainability practices in these institutions would allow to screen for successful policies before implementing them more widely, detecting most effective practices, allowing a faster transition towards achieving the Sustainable Development Goals (SDGs). It is hard to decide where to start, as many sustainable practices exist. This article presents the case study of VILNIUS TECH and conducts a comparison with universities in the region, determining best sustainability practices. The Greenhouse gas (GHG) protocol standard was used to form the emission inventory. The university comparison will help identify effective HEIs carbon footprint minimization practices, as well as other implemented policies as an example of where HEIs should start on their road to a more sustainable institution.

Keywords: GHG accounting, climate neutrality, higher education institutions, decarbonization, Scope 1 emissions, Scope 2 emissions, GHG protocol.

JEL Classification: Q54, Q56, Q59, I23.

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List of abreviations

HEI – Higher education institution;
SDG – Sustainable Development Goals;
VILNIUS TECH – Vilnius Gediminas technical University;
GHG – Greenhouse gas;
CO_2 – Carbon dioxide;
tCO_2e – tons of carbon dioxide equivalent;
CO_2e – Carbon dioxide equivalent;
EU – European Union;
CH_4 – Methane;
PFC – Perfluorocarbon;
N_2O; NOx – Nitrous oxide;
U.K. – United Kingdom;
SAF – Sustainable aircraft fuel.

1. Introduction

Due to a combination of societal pressures, governmental interventions, and legislative frameworks, there is a growing push toward sustainability across virtually all sectors of the economy and throughout society as a whole (Arefin et al., 2021). The European Union has some of the strictest environmental policies in the world, and its institutions have made significant progress in improving the environment (Cifuentes-Faura, 2022). However, many challenges remain. From a social and governmental perspective, these include a lack of solidarity between member states, conflicting policies, insecure funding for sustainability initiatives (Davies et al., 2021; Hermoso et al., 2022), and insufficient public involvement (Khatibi et al., 2021). Environmental problems such as waste disposal, global warming, water pollution, deforestation, and others still persist (Davies et al., 2021; L. Zhang et al., 2022) both in Europe and globally (Rehman et al., 2025; Wang et al., 2024). Additionally, sustainability issues have a significant impact on the economy (Davies et al., 2021; Xu et al., 2024). In addition to these challenges, another issue with pursuing sustainability is its complexity, as it involves various factors that are heavily influenced by the economic and social context in which it is applied, requiring additional education for the people involved (Eichberg & Charles, 2024; Opel et al., 2017). The approach to implementing sustainability should vary depending on whether the focus is on an individual, a company, or a city. A high level of understanding of various fields (economy, climate etc.) is required to properly evaluate the diverse contexts of countries situated in different climate zones, as well as those with urban versus rural environments and varying levels of social and economic development (Aslam & Rana, 2022; Pinuer et al., 2022; X. Zhang et al., 2021). The same rules and regulations apply to Higher Education Institutions (HEI), depending on the location of the university, its most pressing problems, and experiences with policies and education on the environment can differ greatly. An increasing amount of HEIs are incorporating sustainability goals in their policies (Amaral et al., 2021; Minhas et al., 2025; Tallinn University of Technology, 2023) and appropriately adapting their curriculum (Arefin et al., 2021; Minhas et al., 2025). Currently, in Lithuania there is no mandatory requirements for HEIs to report their emissions, however European directives are clear and such regulations will eventually appear for everyone and will need to be adopted by HEIs as well. The precise amount of HEIs tracking their carbon footprint in Europe is hard to determine, but a growing number of universities have decided to provide such information about their institutions. In some countries the majority of universities calculate their carbon footprint: the United Kingdom has a standardized accounting framework, that is followed by 537 institutions (Helmers, 2024), another example is Finland were 97% of HEIs have undertaken the evaluation of their carbon footprint (Sen et al., 2022).

A university and its campus can be considered an appropriate testing ground for sustainability policies and frameworks; usually such institutions are referred to as "living labs" or "small cities" in the literature (Ma et al., 2023; Mustafa et al., 2022; Opel et al., 2017). Universities serve as an ideal environment for developing and testing strategies aimed at achieving zero waste, climate neutrality, and circularity. Higher education institutions consist of people from diverse social and economic backgrounds, they engage in various complex activities, such as teaching and research, with activities continuing throughout the whole day.

This makes them a valuable representation of the broader city population (Bumbiere et al., 2022; Opel et al., 2017). By implementing innovative sustainability initiatives on their campuses (renewable energy, retrofitting buildings, educating staff and students, etc.), universities can demonstrate practical solutions, educate future specialists, and drive societal change towards sustainability goals. Ineffective measures and initiatives can be tested and discarded, while valuable ones can be proposed for adaptation by a wider range of stakeholders, such as companies, cities and countries (Berker et al., 2024).

There are many different measures that can be taken into account when trying to implement sustainability in an HEI: from energy efficiency, renewable energy implementation, lowering carbon emissions, adapting curriculum by including topics about sustainable practices, to educating local community members and focusing on the more social aspects of sustainability, like transparent governance and healthy lifestyle choices. It is sometimes hard to determine and choose where to start and what practices are most efficient in achieving the Sustainable Development Goals (SDGs). There are tools being created to evaluate the sustainability of universities (Dawodu et al., 2022). HEIs are complex institutions that have many different stakeholders so the implementation of sustainable practices is a complicated and long task that cannot be completed instantly and will require incremental changes (Udas et al., 2018), slowly lowering its carbon footprint and consumption rates, educating staff, until finally reaching the climate neutrality target. These changes will also require financial investment, as well as efforts from all the institutions employees. One of the first steps towards a greener university is to create a sustainability plan (Biddlecome et al., 2019) or strategy (Kobylinska et al., 2024; Minhas et al., 2025; Tallinn University of Technology, 2023).

Achieving carbon neutrality is one of the common initiatives undertaken by HEIs (Bumbiere et al., 2022; Mustafa et al., 2022; Tian et al., 2022; Udas et al., 2018). The process of reaching this goal is quite complicated and depends on many different factors including the university size, both in students and owned buildings, the financial state of the institution, the attitude of the leadership and as mentioned before the motivation of all the stakeholders. At this time, only a small percentage of universities have achieved carbon neutrality (Sen et al., 2022). As an example, only 2 universities have achieved this goal in Australia (Sen et al., 2022). Multiple reviews have been conducted worldwide finding only 1–3 universities that have managed to reach zero GHG emissions (Bolivarian University in Colombia, London School of Economics and Political Science etc.) (Sen et al., 2022). As reducing your emissions to zero is unlikely, they are often compensated by implementing different strategies (Lovell & Liverman, 2010): a common practice is to include renewable energy sources (solar energy; geothermal energy, etc.) that generate electricity and heat (Tian et al., 2022), any surplus energy generated after meeting the HEIs' energy needs would displace fossil-fuel-based electricity, thereby reducing CO_2 emissions (Helmers et al., 2021); another method would be to capture carbon dioxide (CO_2) through biomass (planting trees, other plants, etc.) (Bernal et al., 2018; de Villiers et al., 2014; Veludo et al., 2021). Trees conduct photosynthesis, a natural process of removing CO_2 from the air; as an example, Greifswald University offsets unavoidable emissions through increased carbon sequestration on university-owned forested land (Udas et al., 2018). Another applied solution is the purchase of carbon credits to reach the net-zero goal. However, this practice can even have negative effects on sustainable practices as it is more convenient to just buy such credits than implement actual energy and emission saving practices (Melville-Rea & Arndt, 2024). Adding offset to the carbon footprint report raises questions about the methods' transparency and validity.

Scope 1 and Scope 2 emissions are evaluated in this study. Scope 1 consists of university owned emission sources as in fuel combustion for heating, transportation (Hailemariam & Erdiaw-Kwasie, 2023), refrigeration and cooling (World Business Council for Sustainable Development & World Resources Institute [WBCSD & WRI], 2004). While Scope 2 consists of emission sources that are outside of the universities control and are purchased by the university. This emission scope includes purchased energy (electricity, heating, cooling) (Helmers et al., 2021) and may include water (Samara et al., 2022). Scope 3 emissions are all other indirect emissions that are not controlled by the HEI itself. This Scope includes staff and student transport emissions, emissions generated during the creation processes of products and services acquired or provided by the HEI (WBCSD & WRI, 2004).

The aim of this study is to present the case study of Vilnius Gediminas Technical University and its first steps in the long journey to carbon neutrality. Fuel, heating and electricity consumption information is collected and used to calculate Scope 1 (direct) and Scope 2 (indirect) emissions after which a comparison is made with other universities located in Europe, as they have to follow the same policies, regulated by the EU. tCO_2e (tons of CO_2 equivalent) was chosen as a unit of measurement, which will help to determine the university's emissions and compare them to other HEIs. This will help make an informed decision and determine the reasons for differences between HEIs and either adapt better and more efficient solutions offered by other HEIs or propose our own alternatives. An additional goal is to share the university's experience in teaching, emission calculation and other practices related to sustainability as an example of where a university should start its journey towards a more sustainable future, helping them decide which practices to include in their strategies and where to start their decarbonization, with the future goal of implementing these practices on a larger scale and helping policymakers create more effective strategies. The good practices can be proposed for application in VILNIUS TECH, helping it reach its own sustainability goals as well.

2. Methodology

In this chapter all of the collected information on the university's consumption rates are presented, as well as the calculation methodology required to evaluate Scope 1 and Scope 2 emissions, which are generated by the amount of consumed fuel on university grounds (vehicles and HEI owned energy sources) and electricity, heat energy usage for everyday functions. The boundaries of the calculation are presented as well as relevant general information about the university and its renewable sources of energy. A graphical representation of the methodology and results is provided in Figure 1.

There is the possibility of offsetting (through trees, other plants) or another option, capturing CO_2 with technology (physical and chemical processes) and trapping it in geological formations (old mines, oil wells, saline aquifers), however, such an option is not likely to be available for a lot of HEIs and has its own drawbacks (leakage risks, high cost, limited

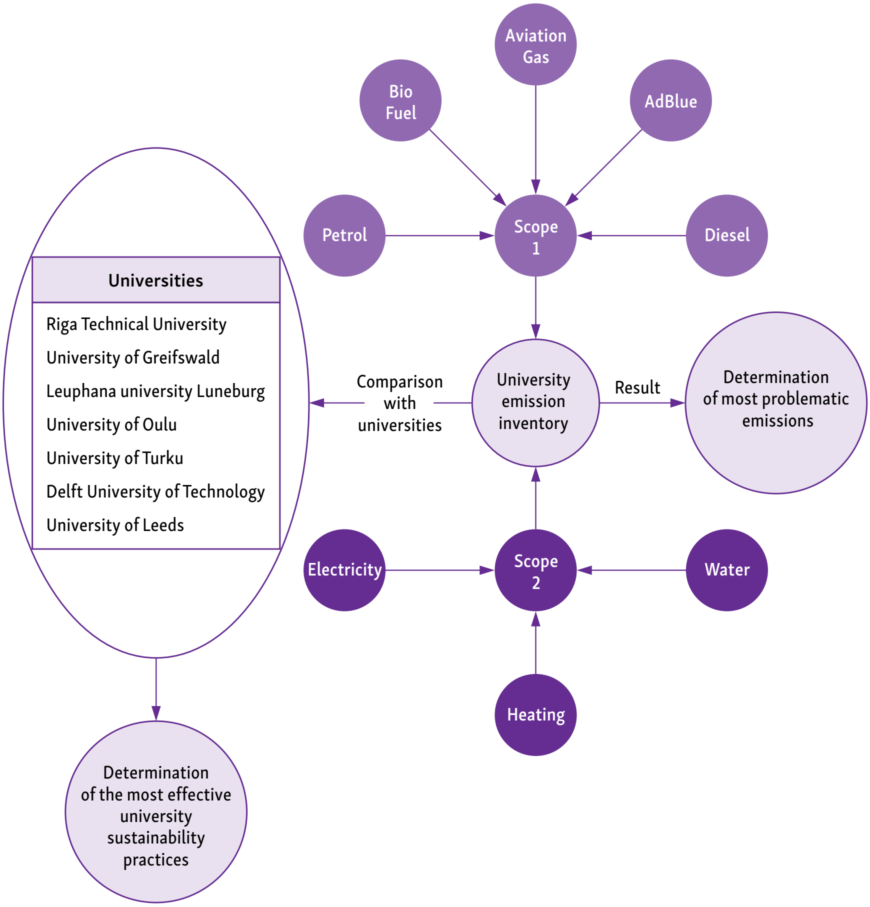

Figure 1. A graphical representation of the methodology of the study

storage) (Ajayi et al., 2019; Fagorite et al., 2023; Veludo et al., 2021). In general carbon emission offsetting is regarded as a very divisive topic and it is debatable how much CO_2 such activities actually save and how to measure different offsetting methods and compare it to generated emission inventories (Ahonen et al., 2024; Helmers et al., 2021; Kiehle et al., 2023). Due to the unclear evaluation methodology, VILNIUS TECH's offsetting projects will not be presented in this study.

2.1. Case study information: VILNIUS TECH

The collection of accurate data is the first step in the process of the calculation of emissions. Yearly consumption reports of electricity, heating and fuel usage were collected from the appropriate departments (Estates and economy office, Finance office) at VILNIUS TECH for the years 2023 and 2024, the data was provided to the appropriate departments by the suppliers (invoices for purchase of biofuel and fuels and billing for the supply of heating and electricity energy). Data from previous years were not included in this article because those years were affected by the COVID-19 pandemic and would not represent the normal functioning of VILNIUS TECH, most emissions moved to Scope 3 during these years, because the majority of the university staff were working remotely and Scope 3 emissions were excluded from this article, making the emissions from those years incomparable. The data included consumption rates on a monthly basis for electricity and heating for all of the separate buildings that are owned or rented by the university, the yearly amount of fuel used for university vehicle and airplane operation (diesel, petrol, aviation gas) and other products (biofuel, AdBlue) that fit the description of the appropriate Scopes, whose yearly consumption rates were available and who emit GHGs. The precise amounts of energy and fuel consumption are provided in Table 1. As can be seen in Table 1 the consumption rates of heating and electricity are slowly increasing, this is because the number of students and staff is increasing (increase from 8123 students in 2023 to 8618 students in 2024, the same for staff, in 2023 there were 1537 employees and 1623 employees in 2024), naturally, which increases the number of and amount of fuel consumed for university owned vehicles. The reasons for this increase in staff and students are due to the merger between VILNIUS TECH and The Lithuanian Maritime Academy and increased student admissions.

Table 1. Consumption rates of energy and products that produce GHGs (emission sources)

Name of energy/product	Year of 2023 consumption	Year of 2024 consumption
Heating energy, MWh	11678	12213
Electricity energy, MWh	4302	4384
Diesel, l	46299	45330
Petrol, l	7543	7609
Aviation fuel AVGAS 100LL, l	189137	143992
AdBlue, l	143	262
Wood pellets, 6mm, t	19.5	16

A more positive observation is the increasing amount of AdBlue which helps mitigate the NOx (Nitrogen Oxides) emissions produced by vehicles using diesel fuel. However, the amount of this type of Greenhouse gas (N_2O) is difficult to accurately determine, because the emission factor varies because of many different vehicle aspects (vehicle, engine, fuel type, operation parameters) (Yaman, 2022), its inclusion in the inventory is determined by whether the emission factor includes this gas. It is clear from the provided amounts of fuel that the majority of Scope 1 emissions will be produced by the exploitation of planes, hence the large amount of aviation gas that was used up (Table 1).

For a more accurate comparison with other universities in regards of efficient resource consumption, the university building area is required to determine the energy consumption rate per square meter of area, taking into account all the owned buildings that are heated and have electricity. The only exception is the Kyviškių Flight training base which is heated by burning wood pellets. Because of the merger the building area increased from 136120 m^2 in 2023 to 142420 m^2 in 2024. Water consumption rates for the years 2023 and 2024 are respectively, 889811 m^3 and 96444 m^3. In 2024 the university started constructing photovoltaic elements on the roofs of university owned buildings that could support such structures.

At the end of the year 518 kWh were generated by the few that were already installed. Renewable energy sources do not count towards HEI emissions in Lithuania as they have an emission factor of zero (Ministry of Environment of the Republic of Lithuania, 2016). During 2025 all of the planned photovoltaic elements will be installed reaching about 382 000 kWh of energy generated which would account for 7.4% of all university used electricity. All of the collected information will be compared with the information provided by similar university case studies conducted in Europe to determine how VILNIUS TECH compares to these HEIs: which of them have better practices implemented that can be adapted to VILNIUS TECH or additional solutions we can suggest to these universities. Because of the similar climate and geography these universities should have similar methodologies implementing sustainability and encounter similar problems while decarbonizing their universities.

2.2. Boundary of carbon emission calculations

The most widely used standard for calculating greenhouse gas emissions (GHG) is the GHG protocol (WBCSD & WRI, 2004). This protocol is mainly focused on businesses, but can also be applied to governmental agencies, non-governmental organizations and universities (Bumbiere et al., 2022; Helmers et al., 2021; Samara et al., 2022; Udas et al., 2018; Yusoff et al., 2021). The protocol allows us to set boundaries for calculating emissions (Scope 1, 2 and 3), because there is a wide variety of greenhouse gases (CO_2, CH4, PFCs etc.) that are produced during many different industrial processes (fuel combustion, concrete setting, refrigeration, etc.), evaluation of all of these GHGs can become very complicated and selectively focusing on just a few while ignoring others could decrease the accuracy of the institutions GHG inventory also leading to the wrong conclusions in trying to decarbonize the HEI. The GHG protocol allows us to convert other GHGs to carbon dioxide equivalents (CO_2e) by using emission coefficients for appropriate emission sources (fuel, heating, etc.). In this article the included GHGs were determined by the available emission factors: the factors provided by the Lithuanian technical regulations (Ministry of Environment of the Republic of Lithuania, 2016; Lithuanian National Energy Regulatory Council, 2014), Commission Implementing Regulation (EU) 2018/2066 from the European Laws (European Commission, 2018) (electricity, heating energy, water, aviation gas and biofuel) only include CO_2, while emissions factors taken from the Department of Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy (U.K.), 2013) include CO_2, N_2O and CH_4 (AdBlue, Diesel, Petrol). The factors from U.K. were taken, because of no available trustworthy emission factors from Lithuania. Emissions are also divided by Scopes (WBCSD & WRI, 2004).

Scope 1 includes direct CO_2 emissions, generated on campus by university owned sources. Scope 1 can include emissions by owned heating, electricity generation systems, university owned vehicles (Hailemariam & Erdiaw-Kwasie, 2023) or refrigeration and air conditioning (WBCSD & WRI, 2004). In the case of VILNIUS TECH, Scope 1 consists of burnt fuel for transportation purposes (diesel, petrol, AdBlue) and fuel for heating during the colder seasons (Wood pellets). The majority of heating for VILNIUS TECH is provided in a centralized manner (district heating), so these emissions are moved to Scope 2. VILNIUS TECH does not have a unified method of reporting refrigeration, air conditioning costs or refrigerant consumption, because all departments track this separately and the third-party providers are not required to report the consumption rates, this is a common problem in universities where there is a lack of systematization of required data (Santos et al., 2024). To include cooling emissions changes, have to be made to the way university tracks cooling and refrigeration costs. Emissions from AdBlue and biofuel (wood pellets) are excluded from the comparison because of their small amount, when compared to the other emissions from vehicle fuel.

Scope 2 emissions are indirect emissions that are produced outside of the control of the HEI and are later purchased by the university, an example being energy resources (electricity, heat). These emissions physically occur at the location where electricity or heat is produced and then are brought into the HEIs boundary, water emissions follow the same pattern as well. Scope 2 emissions for universities usually consist of electricity and heating (purchased energy) (Helmers et al., 2021), in many cases only electricity is taken into account (Bumbiere et al., 2022; Filimonau et al., 2021; Milagre et al., 2023; Mustafa et al., 2022), generally because heating is not an issue in countries with warmer climates or heating systems are owned by the university itself and are reported in Scope 1. As VILNIUS TECH is located in northern Europe and the majority of buildings require district heating, our Scope 2 will consist of heating, electricity and water. Water consumption emissions are included in Scope 2 because it follows the same production and use pattern as electricity or heating, by being produced outside of the university and then supplied to VILNIUS TECH through a centralized manner.

Scope 3 emissions are all other indirect emissions, that occur because of the operations of the institution, but are not controlled by the university itself. This type of emissions can include transportation of staff, emissions produced after selling university products or emissions generated during the creation processes of materials and services acquired by the HEI (WBCSD & WRI, 2004). Scope 3 generates the highest number of emissions, because it is the broadest in the activities included, in some cases it can make up 75% of the total emissions generated by an institution or corporation (Hettler & Graf-Vlachy, 2024).

This is the first time that the GHG inventory will be collected and calculated for VILNIUS TECH. The years 2023 and 2024 were evaluated because they mark the period when the university resumed normal operations after the pandemic, and 2024 was also the year in which the merger between VILNIUS TECH and the Lithuanian Maritime Academy was finalized. Due to uncertainties and complexity of the Scope 3 emissions (Hettler & Graf-Vlachy, 2024; Nguyen et al., 2023) this study will only include the Scope 1 and Scope 2 emissions. For an engineering university the number of different emission categories that need to be evaluated to determine Scope 3 emissions are vast (student and employee travel, product transport, waste utilization etc.) and will require a lot of time to determine accurately. Scope 3 is omitted from this article and will be the focus of future research.

2.3. Greenhouse gas emission inventory: calculation methodology

The collected data is primarily qualitative and based on actual consumption records provided by university departments and suppliers. Basic statistical analysis (e.g., year-to-year comparison, percentage change, and mean values) was applied to assess data trends and ensure consistency. The data was cross-checked for completeness and accuracy to maintain quality and transparency of the emission inventory.

After the data was assessed the methodology for calculating emissions was taken from the standard of the GHG protocol (WBCSD & WRI, 2004) and calculated by applying specific emission factors to the consumed amounts of fuel or products consumed and getting the equivalent CO_2 emissions. The Equation to calculate emissions from fuel consumption or product usage is provided below:

$$C_{PT} \cdot EF_{GHG} = E_{GHG,PT}, \tag{1}$$

the amount of a specific fuel, energy or product type (C_{PT}) is multiplied by the ap-propriate emission factor (EF_{GHG}) to get the equivalent emissions ($E_{GHG,PT}$) for the consumed energy or product type. The most accurate emission factors to apply would be the ones provided by suppliers of the products, but if they are missing, general emission factors are applied: regional factors or factors specified in country regulatory standards. In the case of VILNIUS TECH, the emission factors for electricity, heating energy and biofuel were taken from the technical construction regulations, provided in Chapter 2.2. The factor for water consumption was determined by taking into account the energy required to extract the water and bring it up from a 100 m depth (0.424 kWh/m^3) adding it to the energy needed to get it ready for consumption (0.013kWh/m^3). All required information regarding the determination of emissions from water consumption were taken from National regulations (Chapter 2.2), which specified the appropriate company that supplies water to VILNIUS TECH and its coefficients. The emission factor for Avgas was selected from European Laws, and lastly the emission factors for diesel, petrol and AdBlue were taken from the Department of Energy Security and Net Zero and Department for Business (UK), because of the lack of reliable factors from Lithuania (provided in Chapter 2.2). In some cases, the produced fuel and energy was imported from other countries which makes the determination process a lot more difficult (Aviation fuel). After all the calculations are complete the appropriate GHG emissions are summed up to form Scope 1 and 2 emissions.

After all the calculations are complete, a literature review is conducted and seven case studies of HEIs are selected which have similar climate conditions (experiences winter) are of similar size or close proximity to VILNIUS TECH (located in western, northern Europe) and the most important factor, data about their GHG inventory is publicly available in articles or on their websites: Riga Technical University (Latvia) (Bumbiere et al., 2022), University of Greifswald (Germany) (Udas et al., 2018), Leuphana university Luneburg (Germany) (Opel et al., 2017), University of Oulu (Finland) (Kiehle et al., 2023; Kiehle & Hilli, 2024), University of Turku (Finland) (University of Turku, n.d.), Delft University of Technology (Netherlands) (Herth & Blok, 2022) and University of Leeds (United Kingdom) (Townsend & Barrett, 2015). Scope 1 and Scope 2 emissions are compared between these universities. To make the results clearer the number of emissions per student and per building area are calculated, depending on which information was provided by these universities on their websites or in published articles. An analysis of their activities on sustainability are also investigated, to identify good practices and initiatives.

3. University emission inventory results and comparison

In this section the results of the calculations of Scope 1 and Scope 2 are presented as well as the comparison between the five selected university case studies. Graphs and tables are given to compare the calculated emission amounts per source over a two-year period. Observations are made regarding distribution and dependencies of the results and university data. Reasoning for the differences is provided, as well as recommendations to improve problematic areas, both in compared universities and in VILNIUS TECH.

All calculated emissions for every type of evaluated product and type of energy are provided in Table 2. Emissions from AdBlue (for year 2023, 0.04 tCO_2e and for year 2024, 0.07 tCO_2e) and biofuel (wood pellets) (for year 2023, 0.78 tCO_2e and for year 2024, 0.64 tCO_2e) are excluded from the comparison because they are small and insignificant compared to emissions from other fuels. They are still included in the total amount of emissions for the sake of accuracy because they do create a small amount of emissions (Wood pellets are 0.1% and AdBlue is 0.01% of all Scope 1 emissions) as can be observed in Table 2, if compared to other emission sources. This is because these emission sources (Biofuel, AdBlue) create a more positive impact than a negative one: wood pellets are classified as a renewable energy source (biofuel) in the GHG protocol standard (WBCSD & WRI, 2004) and AdBlue is a compound that negates the creation of NOx from burning diesel fuel, also positively impacting the environment, because of these reasons both these products are not usually included in GHG inventories as no examples were found of cases where they were evaluated.

Water emissions also have little impact. If included in Scope 2, heating and electricity emissions are vastly higher than water emissions (water emissions are equal to 1% of all Scope 2 emissions), but water does create a measurable amount of CO_2 emissions, which cannot be ignored. However, it is not clear to which Scope the water emissions belong to, because the fact that these water emissions are generated outside of university territory and used in university owned buildings should belong to Scope 2. However, other HEI study cases that take water emissions into account have varying opinions on which Scope these emissions

Table 2. GHG emissions produced by the equivalent product and energy consumption

Name of energy/product	Emission factors	Emissions of 2023, tCO_2e	Emissions of 2024, tCO_2e
Heating energy, MWh	0.1 $kgCO_2e/MWh$[1]	1167.8	1221.3
Electricity energy, MWh	0.42 $kgCO_2e/MWh$[1]	1806.7	1841.2
Diesel, l	2.56 $kgCO_2e/l$[2]	118.4	116
Petrol, l	2.16 $kgCO_2e/l$[2]	16.3	16.5
Aviation fuel AVGAS 100LL, l	3.1 $kgCO_2e/l$[3]	586.3	581.2
AdBlue, l	0.24 $kgCO_2e/l$[2]	0.04	0.07
Wood pellets, 6mm, t	0.04 $kgCO_2e/kg$[1]	0.8 t	0.6
Water, m^3	0.437 kWh/m^3[3,4]	16.5	17.7

Notes: [1]Ministry of Environment of the Republic of Lithuania (2016), page 39, table 2.18 (in Lithuanian); [2]Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy (2013), Greenhouse gas reporting: conversion factors 2023, sheet "fuel"; [3]European Commission (2018), page 81, table 1; [4]Lithuanian National Energy Regulatory Council (2014), Table I, Row 14.

should be added. Bumbiere et al. (2022), Filimonau et al. (2021), add it to Scope 3 emissions, Samara et al. (2022), Kiehle et al. (2023) include it in Scope 2, other HEIs like Udas et al. (2018) don't include it in their GHG inventory at all. It is clear from the analyzed literature that there is no unified methodology on water emission evaluation and that it varies between different HEIs. When it is required to report Scope 1 and Scope 2 emissions (because of regulations or providing information for university ranking firms) moving them to Scope 3 might help reduce the actual emissions because Scope 3 emission reporting is not mandatory. This can create a problem of transparency.

The total emissions of VILNIUS TECH for the years 2023 and 2024 are provided in Figure 2. As can be seen in Figure 2, the total amount of emissions in 2023 and 2024 is very similar: 3712.8 tons of CO_2e were generated in 2023 and 3794.5 tons of CO_2e were generated in 2024, an increase of 2.2% can be observed. There was a 3% increase in Scope 2 emissions and a 1.1% decrease in Scope 1 emissions. The decrease in scope 1 emissions can be attributed to normal variation of fuel consumption throughout the years, this change is rather negligible. The increase in Scope 2 emissions is a direct result of VILNIUS TECH merging with The Lithuanian Maritime Academy, increasing the number of students and buildings the university controls (an additional campus and a student housing apartment complex), subsequently increasing the consumption rates of electricity, heating, and water. There should be an additional increase in Scope 1 and 2 emissions in the year 2025, because only 3 months of consumption from The Lithuanian Maritime Academy were included in the emission calculations for the year 2024; at that point in time the two HEIs were merged together. After a whole year passes after the merger the amount of emissions will increase even more; another 6–7% increase in emissions is presumed.

As shown in Figure 2, the largest amount of emissions comes from Scope 2, electricity and heating. Scope 2 emissions are five times higher than Scope 1 emissions and amount to 81% of all university emissions. Scope 2 is more emission heavy than Scope 1 and should be the focus of reduction efforts, at least in the starting phase of decarbonization. Solutions to improve heat and energy efficiency are the ones that will have the most positive effect on the environment, most savings can be achieved here, by implementing energy saving technologies (energy-saving light bulbs, etc.) and renovating the buildings owned by university, savings of electricity and heat will allow to lower the universities carbon footprint.

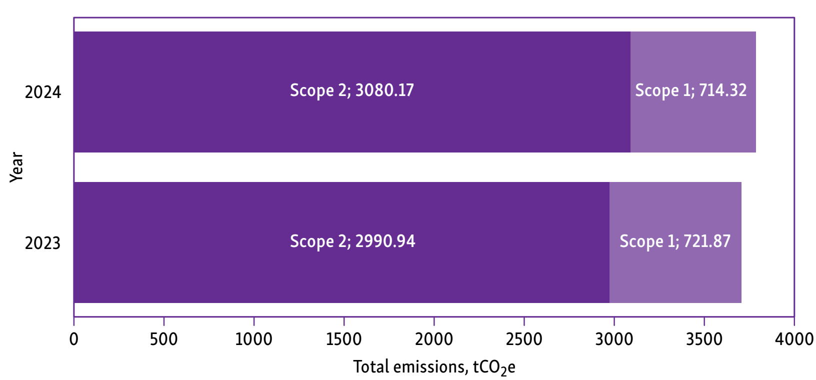

Figure 2. The distribution of emissions by Scope for the years 2023 and 2024 in tCO_2e

A more detailed breakdown of emissions by separate sources is provided in Figure 3 (year 2023) and Figure 4 (year 2024), for Scope 1 emissions and in Figure 5 (year 2023) and Figure 6 (year 2024) for Scope 2 emissions. As mentioned before, it is obvious from the consumption amounts that the most emission heavy source for Scope 1 is aviation fuel (over 80%), while diesel and petrol contributions are much lower, 16–17% and 2%, respectively, for the years 2023 and 2024 (Figures 3–4). While there are reduction strategies for petrol and diesel consumption like the aforementioned vehicles that can reduce emissions by using certain fuel additives (AdBlue) or by changing vehicles to use a more sustainable source of fuel (electricity, hydrogen, biofuel), the aviation industry has not yet achieved so many viable technological alternatives (Abrantes et al., 2021) some possible reduction strategies could be the adoption of different fuel alternatives, like Sustainable Aircraft Fuel (SAF) and improving aircraft design or reducing flying time (Dhara & Muruga Lal, 2021; Marciello et al., 2023). These options have their own negative effects; the option to change fuel or aircraft design would mean the purchase of new aircraft, which would be very expensive, and reducing flying time would negatively impact the abilities of aviation students. There is still a lack of viable options for aviation emission reduction for small and medium-sized HEIs. Additional financial support is required or more time needs to pass for the newly designed aircraft to become more widespread and affordable.

The results of the Scope 2 emissions shown in Figures 4–5 highlight the fact that both heating and electricity are important factors to consider when deciding the reduction strategies for HEIs. Throughout 2023 and 2024, electricity and heating consumption had the most effect on Scope 2 emissions, with the emission distribution remaining the same after the merger with the Lithuanian Maritime Academy. Electricity was the main emission producer at 60% and heating was at 39–40% during the two-year period. These emission sources both have a strong impact on the universities carbon footprint and both need appropriate measures to be introduced to achieve the decarbonization goal.

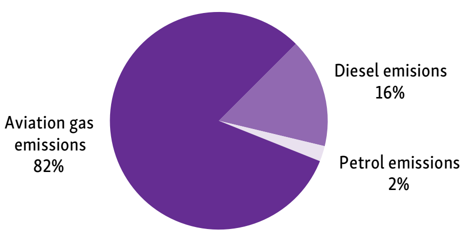

Figure 3. Generated emissions for Scope 1 by source for the year 2023

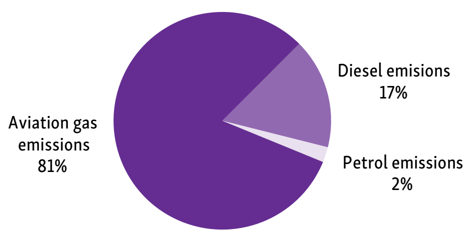

Figure 4. Generated emissions for Scope 1 by source for the year 2024

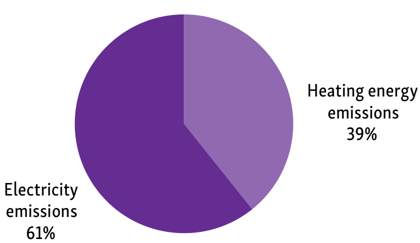

Figure 5. Generated emissions for Scope 2 by source for the year 2023

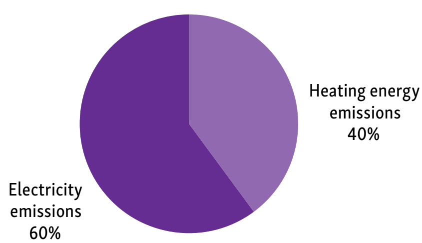

Figure 6. Generated emissions for Scope 2 by source for the year 2024

After the emission amounts were determined for Scope 1 and 2, information regarding the other selected universities was analyzed and a table was compiled to compare the 6 other universities (Table 3). Depending on the available data, emissions per employee/student or emissions per square meter of the area of the universities were compared, as well as the publicly available sustainability practices that were employed in the selected universities. The selected year is determined by the availability of data, the year with the fullest data and closest to the present is selected.

Table 3. Comparison of emissions produced by different HEIs

Name of university	Calculation Year	Building area, m^2	Student/staff number	Total emissions, tCO_2e	Emissions per person, tCO_2e/person	Emissions per area, tCO_2e/m^2
Vilnius Gediminas Technical University	2024	142420	8618/1623	3794.5	0.37[13]	0.027
Riga Technical University	2023	210423[1]	15900/1400[1]	18693[2]	1.08	0.09
University of Greifswald	2021	174285[3]	10366/5601[4]	6098[5]	0.38	0.035
Leuphana university Luneburg	2007–2011, 2015	95000[6]	9700/1000[6]	8398[7]	0.8	0.09
University of Oulu	2019	153413[8]	13500/3400[8]	19072[8]	1.13	0.124
University of Turku	2023	N/A	21900/3400[9]	8600[10]	0.34	N/A
Delft University of Technology	2018	612000[11]	24703/5421[11]	106000[11]	3.5	0.17
University of Leeds	2011	N/A	30761/7144[12]	161819[12]	4.27	N/A

Notes: [1]Bumbiere et al. (2022); [2]Riga Technical University (2024); [3]University of Greifswald (n.d.-a); [4]University of Greifswald (n.d.-c); [5]University of Greifswald (n.d.-b); [6]BOSCH (n.d.); [7]Opel et al. (2017); [8]Kiehle et al. (2023); [9]Kiehle et al. (2023); [10]University of Turku (n.d.); [11]Herth and Blok (2022); [12]Townsend and Barrett (2015); [13]Only includes Scope 1 and Scope 2.

Data was collected from published scientific articles or university websites if the data in the articles was insufficient. It should be stated that the provided information is not always accurate and is not of the same year, because of differing methodologies in the calculation of GHG emissions and general data availability. However, the comparison is accurate enough to allow to form conclusions and determine good practices in regards to sustainability. In the case of these selected universities the methodology used for emission calculation and distribution of results differs. In some cases, the distribution of emissions is not provided (Bumbiere et al., 2022) and the available data is gathered from different sources, in other articles there are no separated Scopes, clearly defined with assigned values (Kiehle et al., 2023; Opel et al., 2017). The distribution is provided in sources, which makes the comparison less accurate because the amount of evaluated Scope 1, 2 and 3 emissions cannot be separated without making assumptions, which means comparing certain Scopes becomes difficult, especially taking into account the fact that certain sources have a tendency to be assigned to different Scopes (in example: water).

A conclusion can be drawn from Table 3 that all of the selected universities produce more emissions than VILNIUS TECH, however this kind of direct comparison (without excluding Scope 3) of the results appears to be inappropriate, as Scope 3 was omitted from the research of VILNIUS TECH. If directly compared, the difference between universities is as follows: GHG emissions per person in Riga Technical University are 66% higher, in University of Greifswald they are 2.9% higher, in Leuphana university Luneburg – 53% higher, in University of Oulu – 67% in University of Turku – 9.1% lower, in Delft University of Technology – 946% higher and in University of Leeds its 1151% higher. If comparing the universities taking into account only a defined Scope 1 and Scope 2 (which are also different by the included sources), the amounts of emissions from different universities become more similar (Table 4): University of Greifswald, has provided Scope 1 and 2 emissions (Scope 1 = 1003 tCO_2e, Scope 2 = 2670 tCO_2e), its emissions per person (only including Scope 1 and 2) is 0.23 tCO_2e. In the same manner, by only comparing Scope 1 and 2 emissions, the amount of tCO_2e per person in Leuphana university Luneburg is 0.3 tCO_2e/person (Scope 2 = 3187 tCO_2e), in University of Oulu – 0.5 tCO_2e/person (Scope 1 = 322 tCO_2e, Scope 2 = 7783 tCO_2e), in Delft University of Technology – 0.6 tCO_2e/person (Scope 1 = 17595 tCO_2e, Scope 2 = 631 tCO2e), in University of Leeds – 2.09 tCO_{2e}/person (Scope 1 = 29127 tCO_2e, Scope 2 = 50164 tCO_2e). Riga Technical University and University of Turku does not provide a more detailed breakdown of their emissions by Scope. A graphical representation of these results is provided in Figure 7.

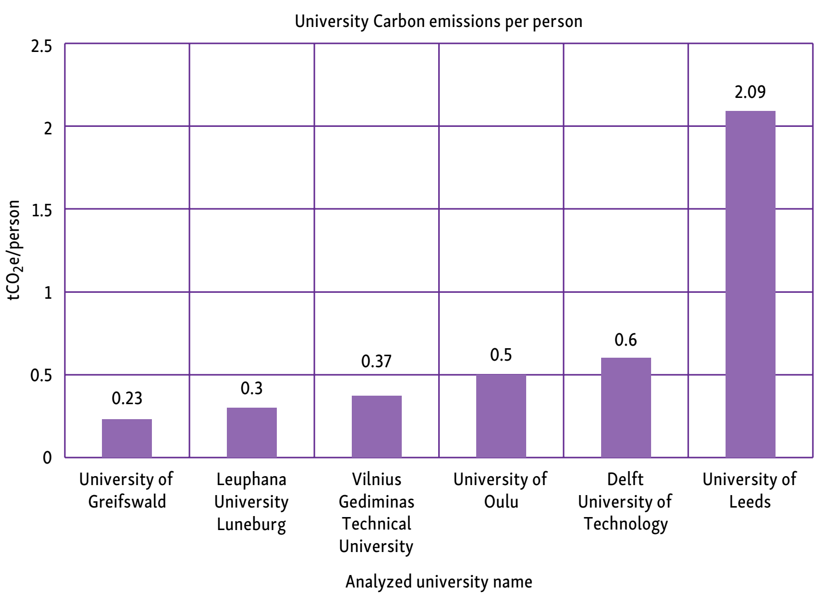

Figure 7. Selected university Scope 1 and 2 emissions generated per person

When only Scope 1 and 2 is taken into account the selected universities produce less or a similar amount of emissions per person compared to VILNIUS TECH, which is to be expected because these universities have been seeking for carbon neutrality for a longer period of time than VILNIUS TECH. Three universities produce more Scope 1 and 2 emissions than VILNIUS TECH. The university of Oulu, which has more emissions from heating than VILNIUS TECH, because of their geographical location and colder winters (heating emissions are 40.6% of all emissions in 2019 (Kiehle et al., 2023)); Delft University of Technology produces around 61% more Scope 1 and 2 emissions per person than VILNIUS TECH, but this is because of the natural gas used for heating, which is the second most emission heavy source in their university (Herth & Blok, 2022); University of Leeds have an almost 6 times higher Scope 1 and 2 emission count, but it is impossible to determine the reasons because the available data is not detailed enough (Townsend & Barrett, 2015). The data selected to be used for the comparison was taken from the most detailed years, if talking about 2025, these universities have already moved even further forward in their decarbonization efforts and some of them have declared carbon neutrality (Leuphana university Luneburg). Another observation regarding the comparison is that a rough estimation can be made from table 3 on the increase of emissions when Scope 3 will be evaluated. If assuming that the amount of emissions for Scope 1 and Scope 2 are similar in these universities, then the major differences between these HEIs are because of Scope 3 emissions (not taking into account that these HEIs have already applied various sustainability measures and the emission amounts slightly differ between all universities). The difference between VILNIUS TECH and the selected universities in the direct comparison, which is between 50–70% (Riga Technical University, Leuphana university Luneburg, University of Oulu), can be assumed to be the amount of emissions that will increase because of the evaluation of Scope 3, which is also backed up by the figures found in the literature (increase by up to 75% of Scope 1 and 2 emissions (Hettler & Graf-Vlachy, 2024)). It has to be noted that this assumption does not apply to HEIs that have already eliminated the majority of Scope 3 emissions or are close to completing this goal (University of Greifswald, University of Turku). The amount of Scope 3 emissions have a tendency to increase beyond this range, depending how much building area a university owns (Delft university of Technology). To more thoroughly verify these observations more accurate data about the university building area is required as in some cases it is missing (University of Turku, University of Leeds). It is also possible that the size of the institution (University of Leeds), the type and amount of study fields the HEI covers has an influence on total emissions (some emission sources are harder to minimize (example: aviation)). It is likely that universal reporting standards for HEIs will be impossible to implement and will have to take into account the different types of universities, their size and study fields. This requires a more thorough analysis and could be a topic for future research.

A possible way to evaluate different university Scope 2 emissions is with the help of a climatic analysis utilizing the degree day (DD) method. Emissions from heating systems have a significant impact on Scope 2 values. A degree day is a climatic measurement unit that shows the amount of energy needed to heat or cool buildings. Heating degree days show the amount of energy needed to heat buildings, while cooling degree days show the amount of energy needed to cool buildings. Degree days are calculated for different time intervals such

Table 4. Comparison of Scope 1 and 2 emissions produced by different HEIs (year as in Table 3).

Name of university	Scope 1 emissions, tCO_2e	Scope 2 emissions, tCO_2e	Sources included in Scope 1	Sources included in Scope 2	Scope 3 emissions, tCO_2e
Vilnius Gediminas Technical University	714	3080	Car fleet fuel (diesel, petrol, AdBlue); Aviation fuel; Biofuel (Wood pellets).	Heating energy; Electricity; Water consumption.	N/A
University of Greifswald	1003[1]	2670[1]	Work-related travel, excursions and the use of the vehicle fleet[1]	Energy and heat supply of buildings[1]	2425[1]
Leuphana university Luneburg	Not clearly defined	3187[2]	Not clearly defined	Energy and heat supply of buildings[2]	5211[2]
University of Oulu	322[3]	7783[3]	Car fleet; Direct fuel combustion for heating; cooling[3]	Heat supply; Water consumption; Electricity is not included, because fully renewable[3]	10966[3]
Delft University of Technology	17595[4]	631[4]	Natural gas for heating; electricity generation[4]	Electricity supply[4]	87712[4]
University of Leeds	29127[5]	50164[5]	Not clearly defined	Electricity supply[5]	82528[5]

Notes: [1]University of Greifswald (n.d.-b); [2]Opel et al. (2017); [3]Kiehle et al. (2023); [4]Herth and Blok (2022); [5]Townsend and Barrett (2015).

as year, season or month and are determined by adding the temperature anomaly between the base temperature and the mean daily air temperature (Tantekin, 2025). In this study we focus on heating degree days because the countries with comparable data are located in temperate and cold climate zones. In these countries, cooling demand is not a significant factor. The Equation for calculating degree days is provided below:

$$HDD = \left(t_{indoor} - t_{aver.season}\right) \cdot n, \tag{2}$$

the average outdoor temperature of the heating season($t_{aver.season}$, °C) is subtracted from the average country indoor temperature (t_{indoor}, °C) and the result is multiplied by the number of heating season days (n). This process is repeated for all the different analysed countries. The data is taken from a 10-year average, from 2015 to 2024 (Eurostat, n.d.). In the case of the U.K. data from Ireland was used, because of their proximity. The values of all the different country degree-days are presented in Table 5.

After average heating degree-days are determined for every country the amount of Scope 2 emissions per degree-day can be calculated, helping determine the efficiency of Scope 2 emission reduction strategies in the selected universities. Scope 2 emissions per degree-day are provided in Table 6.

Table 5. Different country heating degree-day averages (2015–2024)

Country	Reference heating degree-days (average of the last 10 years of heating seasons) (Eurostat, n.d.)
Finland	5303
Lithuania	3597
Germany	2828
UK (Ireland data)	2672
Netherlands	2274

Table 6. University Scope 2 (with Scope 1 heating emissions) per degree-day

Name of university	Scope 2 emissions, tCO_2e	Scope 2 emissions, tCO_2e/DD
Vilnius Gediminas Technical University	3080	0.86
University of Greifswald	2670	0.94
Leuphana university Luneburg	3187	1.13
University of Oulu	7783+5 (Scope 1 heating)	1.46
Delft University of Technology	631+2990 (Scope 1 heating)	1.59
University of Leeds	50164	18.77

It is clear that universities with larger populations of staff and students (University of Oulu, Delft University of Technology, University of Leeds) naturally have higher Scope 2 emissions per degree-day (Table 6), as the emissions from heating and electricity would be higher for these HEIs. However, the analysis in determining heating strategy efficiency could be improved if separate data was provided about heating emissions, regardless of Scope. University of Leeds is the only institution that has a many times higher emission amount compared to other HEIs and could benefit from additional measures to decrease such emissions, but it is difficult to tell the exact reason because of a lack of detailed data.

The selected universities have provided information on the solutions they have applied to achieve the goal of carbon neutrality. To reduce the CO_2 emissions regarding Scope 2 (heating and electricity) application of energy saving policies is a common practice, as well as renovation of existing buildings (Kiehle et al., 2023; Opel et al., 2017), to further lower energy consumption emissions, the implementation of renewable energy sources is a commonly applied solution, which is extremely effective in reducing emissions (Bumbiere et al., 2022). This can be applied to electricity consumption as well as heating energy consumption. For a lone HEI to change the whole energy procurement methodology would be extremely expensive, in those cases it is more economically viable to wait till the providers of electricity or heating energy start implementing renewable sources, as they have to follow the same legislation as universities. It is also possible to change suppliers of electricity, choosing suppliers that include more energy from renewable sources in their power mix. After suppliers change their energy extraction methods it is important to re-evaluate the emission factors while conducting GHG inventories as they are likely to decrease, in turn decreasing the HEIs generated emissions. For the consumption of all resources, it is important to implement sustainability teachings just as much for staff as for students, this will have a positive effect on consumption rates of products and energy, reducing emissions (Kiehle et al., 2023; Udas et al., 2018). Universities are including sustainability in its curriculum and providing training both for the staff and students (Greifswald University (Kiehle et al., 2023; Udas et al., 2018)). VILNIUS TECH has also created bachelor (Sustainability Technologies) and master (Sustainability Management) study programmes to increase awareness about sustainable practices and resource conservation. Also providing complimentary elective courses for students. Such awareness raising policies would have an effect on Scope 1 and 2 and 3. While Scope 1 can be reduced by replacing petrol and diesel driven vehicles with hybrid, gas or electricity driven cars (Bumbiere et al., 2022; Udas et al., 2018). Of note is that the decarbonization of a HEI is a very long process and cannot be completed quickly. Starting as early as possible would help fitting into the legislatively set time frames.

4. Discussion

A Scope 1 and 2 full GHG emission inventory was done in VILNIUS TECH for years 2023 and 2024, also a comparison between similarly geographically located universities was conducted, comparing their total Scope 1 and Scope 2 emissions and highlighting the best adopted practices.

The GHGs included in the study were determined by the available emissions factors. Factors chosen from regulatory documents and laws only include CO_2, they are used for the evaluation of electricity, heating energy, water, aviation gas and biofuel, while the emission factors taken from the Department of Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy (U.K.) include CO_2, N2O and CH4 and were used to calculate AdBlue, diesel and petrol emissions. Currently there are no emission factors that evaluate generated GHGs from vehicle fuel available in Lithuania, while other factors (electricity, heating energy, water, aviation gas and biofuel) do not include all of the generated GHGs, only CO2. Because of the lack of inclusion for different generated GHGs the inventories accuracy decreases. This inventory demonstrates the lack and need for emission factors, especially on a local level. In the case of the used fuel, emission factors from the U.K. were utilized, they would likely be lower if they were available in Lithuania as Britain is an island nation and the import of such fuel would be more expensive and require additional transport, which would also increase GHG emissions. As the availability of trustworthy emission factors is very important to the accuracy of the GHG inventory, the determination of these factors could be a topic for future research.

The inventory showed that the main contributor to Scope 1 emissions was aviation gas while the contribution of university's car fleet was below 20% (Figures 3–4). Reduction efforts to reduce vehicle emissions are already underway at VILNIUS TECH – the first electric cars have already been purchased at the beginning of 2025. This possible solution to lower Scope 1 emissions was determined from the HEI comparison as it was implemented by other institutions (Bumbiere et al., 2022; Udas et al., 2018). Also, the amount of AdBlue purchased increased by 45% from year 2023 to year 2024, reducing NOx emissions. A problem arises with aviation emissions, where there is no clear solution how to reduce them without heavy expenses in replacing aircraft or decreasing flying time, and damaging student competencies.

Another issue with Scope 1 emissions is the exclusion of refrigeration, air conditioning emissions from this inventory, because all university departments track these sources separately and the third-party providers are not required to report the consumption rates. Changes need to be made to the way VILNIUS TECH tracks refrigeration emissions.

Scope 2 emissions consist of heating energy, electricity and water consumption. The largest contributor was electricity emissions (~60%), with heating second (~40%), as can be seen in Figures 5–6. A common reduction strategy is the renovation of existing university buildings and energy saving policies, including the education of students and staff (Kiehle et al., 2023; Opel et al., 2017). Another method to decrease Scope 2 emissions is the purchase of electricity from carbon neutral suppliers or installing renewable energy sources, such as photovoltaic elements (Bumbiere et al., 2022). Even though water consumption emissions are the lowest, water is still a valuable resource that should be preserved, and many reduction strategies exist (Bumbiere et al., 2022; Samara et al., 2022). Water consumption can be limited by integrating water aerators and installing modern flush systems, as well as collecting and integrating rainwater for toilets, laboratories, etc. (Bumbiere et al., 2022). VILNIUS TECH has already started implementing modern flush systems in bathrooms and automated sinks have been installed to save excess water. Currently these reduction strategies are only applied to some of the buildings owned by VILNIUS TECH, but in the upcoming 5–10 years' renovations of all the university buildings are planned, which will include installing these solutions throughout the whole university.

The concept of sustainable university development (VILNIUS TECH, 2021) has been written to start the university on the path of sustainability, which sets goals for the implementation of all the 17 Sustainable Development Goals (SDGs). VILNIUS TECH has opened its Sustainability HUB, to oversee the implementation of sustainable practices in all the universities activities, proposing measures aligned with strategic objectives, developing and updating action plans, advising the university community and partners, organizing sustainability-related events, and providing guidance on energy efficiency, resource conservation, climate resilience, and greenhouse gas emissions. It is the only one of its kind in Lithuania. As part of the project, "The establishment of the Integrated Sustainability Technologies Laboratory" at VILNIUS TECH, funded by the Economic Revival and Resilience Plan "New Generation Lithuania" and the state budget of the Republic of Lithuania, in 2023 new study programmes were created – Sustainability Technologies (bachelor study programme) and Sustainability Management (masters study programme), for guiding students through topics such as Sustainable Environment and Society, Environmental Systems Processes, Circular Economy and Sustainable Resource Management, and Climate Change Mitigation Engineering, allowing them to mitigate adverse environmental impacts (Sustainability Technologies) and managing organizations based on Sustainable Development Goals (Sustainability Management). In addition to introducing two dedicated study programmes focused on sustainability, the university actively incorporates sustainability principles into various other study subjects and modules (Renewable Energy Systems (with course project) (APPEM17308), Energy Demand Management (APPEM17309), Sustainable Business Development (VVVKM21200) etc.). Furthermore, the university offers a selection of complimentary elective courses, which either directly explore sustainability topics or seamlessly incorporate and address sustainability topics (The Utilization of Waste and Recycled Materials in Sustainable Construction (STGSB93239), Sustainable Management of Water Resources (APAVM 91011) etc.). Currently, the universities decarbonization strategy is being developed, with 2050 being the year the university plans to reach carbon neutrality.

It is clear from the conducted HEI comparison that there is a lack of a unified emission reporting methodology, it is hard to determine the exact emission distribution by Scopes, because every university, names sources differently and may assign different sources to different Scopes, which makes a direct comparison inaccurate or even impossible, being the biggest limitation of this study. After collecting data about seven universities which all are located in Europe and experience similar climate conditions (Vilnius Gediminas Technical University (Lithuania), Riga Technical University (Latvia), University of Greifswald (Germany), Leuphana University Luneburg (Germany), University of Oulu (Finland), University of Turku (Finland), University of Leeds (UK), Delft University of Technology (Netherlands)), their emissions per person (staff and students) were determined. While a direct comparison not taking Scopes into account showed that VILNIUS TECH is on the lower end of GHG emissions, a more detailed analysis comparing selected university Scope 1 and 2 emissions separately showed that VILNIUS TECH has a long way to go to catch up. Taking into account inaccuracies and a lack of data, the difference could be even greater. All of the selected universities evaluated Scope 3 emissions with varying degrees of source inclusion, which allows to make a conservative estimate (disregarding already included reduction strategies at these HEIs) that Scope 3 emissions could possibly increase by another 52–67%, which was also supported by the literature (Hettler & Graf-Vlachy, 2024).

The comparison also helped determine implementable practices to decrease emissions from Scopes 1 and 2: universities included in the comparison decreased Scope 1 emissions by buying electric vehicles (Bumbiere et al., 2022; Udas et al., 2018; Kiehle et al., 2023), gas operated cars or introducing service bicycles (Udas et al., 2018). Generally, articles don't concentrate on solutions for car fleet emissions (as practical solutions already exist), mainly focusing on the emissions generated by university owned heating sources, as they generate comparatively more emissions and are more difficult to implement as solutions require changes to infrastructure. Mentioned solutions being either switching to district heating (Udas et al., 2018) or substitution with other heating technology (Biomass boiler, solar collector) (Bumbiere et al., 2022). Viable strategies to decrease Scope 2 emissions include the change of suppliers both for heating and electricity, that produce the energy from more sustainable sources, but the most mentioned solutions are the implementation of renewable energy sources (Opel et al., 2017; Bumbiere et al., 2022; Udas et al., 2018; Herth & Blok, 2022), generated electricity can be also used for heating purposes (Opel et al., 2017), and the renovation of existing university owned buildings (Bumbiere et al., 2022; Udas et al., 2018; Herth & Blok, 2022), making them more energy efficient. Another mentioned solution that has a positive effect for all 3 Scopes is the training and informing of the university community (Bumbiere et al., 2022; Udas et al., 2018), this leads to savings both in energy and fuel as well as other consumed products covered by Scope 3 (office supplies, waste). A climatic analysis was also completed evaluating Scope 2 emissions per degree-day, helping understand the influence of climate on Scope 2. Some of the identified solutions are already being implemented in VILNIUS TECH: inclusion of sustainability in the curriculum, renovation of buildings, the replacement of the car fleet and implementation of renewable sources of energy. These solutions still need to be expanded on a wider scale as well as a possible solution for heating needs to be determined if emissions are to be decreased to a minimum. The possibility of changing district heating to a more sustainable source has been identified (biofuel boilers, solar collectors).

For a more accurate comparison, the source and Scope distribution throughout the years should be kept, something VILNIUS TECH is planning to do. With a greater number of detailed reports, it would be easier to assess the effects of reduction methods, highlighting best practices. However, for a university starting its journey in sustainability the amount of solutions currently being implemented is enough and the direction highlighted by these HEIs is clear. A topic for future research should be the evaluation of Scope 3 emissions, as this Scope can be the highest source of GHG emissions and the most difficult to assess accurately.

5. Conclusions

In this study we calculate the carbon footprint of VILNIUS TECH and compare the findings to other similar universities in the region, to determine the most efficient practices, that later can be adapted to other universities in the region, that are starting to implement sustainability, in their curriculum and decarbonize their campuses. After thorough investigation the identified practices could be applied on a larger scale (cities, companies etc.). Scope 1 and Scope 2 emissions are calculated as a first step towards decarbonizing the university of VILNIUS TECH with the biggest challenge being data availability (emission factors not provided in national documents, suppliers not willing to provide these factors). Starting the decarbonization process and determining the first inventory is possible even while using such heterogeneous sources for emission factors, as this first step is necessary to acquire an understanding about the HEIs emission situation, however these factors become even more important the closer to carbon neutrality the HEI advances, as they are the only solution to guarantee accuracy. Emission factors provided by suppliers are preferable as they are most accurate, but factors created for countries or regions are also viable, for certain sources it is also possible to determine these factors experimentally. Additional legislation, laws are required determining and introducing such factors or making suppliers more willing to provide them (making them publicly available). Scope 1 emissions included car fleet emissions and aviation emissions, with aviation emissions being the biggest contributor, with little solutions provided by other universities, outside of replacing all the aircraft. Scope 2 emissions included electricity heating and water usage emissions, with electricity being the number one contributor to emissions in VILNIUS TECH, a solution to decrease these emissions being the renovation of university owned buildings and education of the VILNIUS TECH community. Of note is the lack of a unified methodology in the calculation, distribution and presentation of emissions in different HEIs. The data provided by different universities is usually incomplete (missing emission factors, unclear, differing distribution of sources by Scope), which limits the accuracy of the university comparison. There is a lack of a unified methodology in emission reporting which creates a lack of transparency. Calculated emissions for VILNIUS TECH (Scope 1 and 2) per person are 0.37 tCO_2e, while the University of Greifswald emissions were 0.23 tCO_2e

(39% lower), the Leuphana university Luneburg were 0.3 tCO_2e (24.5% lower), the University of Oulu were 0.5 tCO_2e (23% higher), University of Leeds were 2.09 tCO_2e (564% higher), Delft University of Technology were 0.6 tCO_2e (61% higher). The selected universities have been compared and the most common practices have been discovered. These practices now can be adapted by other universities starting to implement sustainability goals in their campuses.

Author contributions

Conceptualization, R. G., M. G., V. Š., R. M.; methodology, M. G.; validation, M. G., R. G.; formal analysis, M. G., R. G.; resources, M.G.; data curation, M. G.; writing – original draft preparation, M. G.; writing – review and editing, M. G. and V. Š.; visualization, M. G.; supervision, R. G. All authors have read and agreed to the published version of the manuscript.

Disclosure statement

The authors declare no conflicts of interest.

References

Abrantes, I., Ferreira, A. F., Silva, A., & Costa, M. (2021). Sustainable aviation fuels and imminent technologies – CO_2 emissions evolution towards 2050. *Journal of Cleaner Production*, *313*, Article 127937. https://doi.org/10.1016/j.jclepro.2021.127937

Ahonen, V. L., Woszczek, A., Baumeister, S., Helimo, U. T., Jackson, A. K., Kopsakangas-Savolainen, M., Kääriä, J., Lehtonen, T., Luoranen, M., Pongrácz, E., Soukka, R., Vainio, V., & El Geneidy, S. (2024). Carbon neutral higher education institutions: A reality check, challenges and solutions. *International Journal of Sustainability in Higher Education*, *25*(9), 293–315. https://doi.org/10.1108/IJSHE-11-2023-0515

Ajayi, T., Gomes, J. S., & Bera, A. (2019). A review of CO_2 storage in geological formations emphasizing modeling, monitoring and capacity estimation approaches. *Petroleum Science*, *16*, 1028–1063. https://doi.org/10.1007/s12182-019-0340-8

Amaral, A. R., Rodrigues, E., Gaspar, A. R., & Gomes, Á. (2021). Lessons from unsuccessful energy and buildings sustainability actions in university campus operations. *Journal of Cleaner Production*, *297*, Article 126665. https://doi.org/10.1016/j.jclepro.2021.126665

Arefin, M. A., Nabi, M. N., Sadeque, S., & Gudimetla, P. (2021). Incorporating sustainability in engineering curriculum: A study of the Australian universities. *International Journal of Sustainability in Higher Education*, *22*(3), 576–598. https://doi.org/10.1108/IJSHE-07-2020-0271

Aslam, A., & Rana, I. A. (2022). The use of local climate zones in the urban environment: A systematic review of data sources, methods, and themes. *Urban Climate*, *42*, Article 101120. https://doi.org/10.1016/j.uclim.2022.101120

Berker, T., Henriksen, H., Sutcliffe, T.E., & Woods, R. (2024). A sustainable campus for an uncertain future. Two cases of infrastructural transformation at Norway's largest university. *International Journal of Sustainability in Higher Education*, *25*(6), 1198–1213. https://doi.org/10.1108/IJSHE-01-2023-0027

Bernal, B., Murray, L. T., & Pearson, T. R. H. (2018). Global carbon dioxide removal rates from forest landscape restoration activities. *Carbon Balance and Management*, *13*, Article 22. https://doi.org/10.1186/s13021-018-0110-8

Biddlecome, C., Muñoz, G., Newton, M., Payne, C., Selvig, A., & Thompson, P. (2019). *The road to carbon neutrality*: *Franklin University Switzerland's climate action plan*. https://www.fus.edu/files/FUSClimateActionPlan.pdf

BOSCH. (n.d.). *More than 95,000 square meters of sustainability*. https://www.boschbuildingsolutions.com/xc/en/news-and-stories/leuphana/

Bumbiere, K., Barisa, A., Pubule, J., Blumberga, D., & Gomez-Bavarro, T. (2022). Transition to climate neutrality at university campus. Case study in Europe, Riga. *Environmental and Climate Technologies*, *26*(1), 941–954. https://doi.org/10.2478/rtuect-2022-0071

Cifuentes-Faura, J. (2022). European Union policies and their role in combating climate change over the years. *Air Quality*, *Atmosphere and Health*, *15*(8), 1333–1340. https://doi.org/10.1007/s11869-022-01156-5

Davies, C., Chen, W. Y., Sanesi, G., & Lafortezza, R. (2021). The European Union roadmap for implementing nature-based solutions: A review. *Environmental Science and Policy*, *121*, 49–67. https://doi.org/10.1016/j.envsci.2021.03.018

Dawodu, A., Dai, H., Zou, T., Zhou, H., Lian, W., Oladejo, J., & Osebor, F. (2022). Campus sustainability research: Indicators and dimensions to consider for the design and assessment of a sustainable campus. *Heliyon*, *8*(12), Article e11864. https://doi.org/10.1016/j.heliyon.2022.e11864

De Villiers, C., Chen, S., Jin, C., & Zhu, Y. (2014). Carbon sequestered in the trees on a university campus: A case study. *Sustainability Accounting*, *Management and Policy Journal*, *5*(2), 149–171. https://doi.org/10.1108/SAMPJ-11-2013-0048

Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy. (2013). *Government conversion factors for company reporting of greenhouse gas emissions*. https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

Dhara, A., & Muruga Lal, J. (2021). Sustainable Technology on aircraft design: A review. *IOP Conference Series*: *Earth and Environmental Science*, *889*, Article 012068. https://doi.org/10.1088/1755-1315/889/1/012068

Eichberg, E. T. A. M., & Charles A. (2024). The role of the Civic University in facilitating inclusive and transformative pedagogical approaches to the sustainable development goals: A systematic literature review. *Sustainability*, *16*(7), Article 2752. https://doi.org/10.3390/su16072752

European Commission. (2018). *Commission Implementing Regulation* (*EU*) *2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation* (*EU*) (2018, December 19, No 601/2012). Official Journal of the European Union, 10(L 334). https://eur-lex.europa.eu/eli/reg_impl/2018/2066/oj/eng

Eurostat. (n.d.). *Cooling and heating degree days by country – annual data* [data set]. https://doi.org/10.2908/NRG_CHDD_A

Fagorite, V. I., Onyekuru, S. O., Opara, A. I., & Oguzie, E. E. (2023). The major techniques, advantages, and pitfalls of various methods used in geological carbon sequestration. *International Journal of Environmental Science and Technology*, *20*, 4585–4614. https://doi.org/10.1007/s13762-022-04351-0

Filimonau, V., Archer, D., Bellamy, L., Smith, N., & Wintrip, R. (2021). The carbon footprint of a UK University during the COVID-19 lockdown. *Science of the Total Environment*, *756*, Article 143964. https://doi.org/10.1016/j.scitotenv.2020.143964

Hailemariam, A., & Erdiaw-Kwasie, M. O. (2023). Towards a circular economy: Implications for emission reduction and environmental sustainability. *Business Strategy and the Environment*, *32*(4), 1951–1965. https://doi.org/10.1002/bse.3229

Helmers, E., Chang, C. C., & Dauwels, J. (2021). Carbon footprinting of universities worldwide: Part I – objective comparison by standardized metrics. *Environmental Sciences Europe*, *33*, Article 30. https://doi.org/10.1186/s12302-021-00454-6

Helmers, E. (2024). Do’s and don’ts in climate impact assessment of University campuses: Towards responsible, transparent and comprehensive reporting. *Sustainability*, *16*(21), Article 9320. https://doi.org/10.3390/su16219320

Hermoso, V., Carvalho, S. B., Giakoumi, S., Goldsborough, D., Katsanevakis, S., Leontiou, S., Markantonatou, V., Rumes, B., Vogiatzakis, I. N., & Yates, K. L. (2022). The EU biodiversity strategy for 2030: Opportunities and challenges on the path towards biodiversity recovery. *Environmental Science and Policy*, *127*, 263–271. https://doi.org/10.1016/j.envsci.2021.10.028

Herth, A., & Blok, K. (2022). Quantifying universities' direct and indirect carbon emissions – the case of Delft University of Technology. *International Journal of Sustainability in Higher Education*, *24*(9), 21–52. https://doi.org/10.1108/IJSHE-04-2022-0121

Hettler, M., & Graf-Vlachy, L. (2024). Corporate scope 3 carbon emission reporting as an enabler of supply chain decarbonization: A systematic review and comprehensive research agenda. *Business Strategy and the Environment*, *33*(2), 263–282. https://doi.org/10.1002/bse.3486

Khatibi, F. S., Dedekorkut-Howes, A., Howes, M., & Torabi, E. (2021). Can public awareness, knowledge and engagement improve climate change adaptation policies? *Discover Sustainability*, *2*, Article 18. https://doi.org/10.1007/s43621-021-00024-z

Kiehle, J., Kopsakangas-Savolainen, M., Hilli, M., & Pongrácz, E. (2023). Carbon footprint at institutions of higher education: The case of the University of Oulu. *Journal of Environmental Management*, *329*, Article 117056. https://doi.org/10.1016/j.jenvman.2022.117056

Kiehle, J., & Hilli, M. (2023). *The Carbon Footprint of the University of Oulu Data collection 2022*. https://www.silven.fi/wp-content/uploads/2024/01/CF_data-collection_2022.pdf

Kobylinska, U., Goni, M.G., Rollnik-Sadowska, E., Szpilko, D., Szydlo, J., & Grabowska, P. (2024). Student's perception of sustainable university – on the example of Bialystok University of Technology. *Economics and Environment*, *89*(2), Article 837. https://doi.org/10.34659/eis.2024.89.2.837

Lithuanian National Energy Regulatory Council. (2014). *Vandens sektoriaus rodikliai* [Water sector indicators]. https://www.regula.lt/vanduo/Puslapiai/vandens-sektoriaus-rodikliai.aspx

Lovell, H., & Liverman, D. (2010). Understanding carbon offset technologies. *New Political Economy*, *15*(2), 255–273. https://doi.org/10.1080/13563460903548699

Ma, B., Bashir, M. F., Peng, X., Strielkowski, W., & Kirikkaleli, D. (2023). Analyzing research trends of universities' carbon footprint: An integrated review. *Gondwana Research*, *121*, 259–275. https://doi.org/10.1016/j.gr.2023.05.008

Marciello, V., Di Stasio, M., Ruocco, M., Trifari, V., Nicolosi, F., Meindl, M., Lemoine, B., & Caliandro, P. (2023). Design exploration for sustainable regional hybrid-electric aircraft: A study based on technology forecasts. *Aerospace*, *10*(2), Article 165. https://doi.org/10.3390/aerospace10020165

Melville-Rea, K., & Arndt, S. K. (2024). Net-zero heroes? Climate change mitigation efforts and strategies across Australian Group-of-Eight Universities. *Sustainability*, *16*(7), Article 2937. https://doi.org/10.3390/su16072937

Milagre, J. C., Mendes, L. J., Torres, C. M. M. E., Pereira, M. C., Dick, G., Schumacher, M. V., & De Morais, V. T. M. (2023). GHG emissions and removals of a federal institute campus from Brazil. *Scientia Forestalis/Forest Sciences*, 51, Article e3935. https://doi.org/10.18671/scifor.v51.09

Minhas, W., Abdulmouti, H., Skaf, Z., Saleh, M. (2025). The sustainable university: Creating societal impact, the next step! *Journal of Applied Research in Higher Education*. https://doi.org/10.1108/JARHE-01-2025-0047

Ministry of Environment of the Republic of Lithuania. (2016). *On the approval of the construction technical regulation STR 2.01.02:2016 „Design and certification of the energy performance of buildings"* (2016, November 11, No. D1-754). https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/15767120a80711e68987e-8320e9a5185/sCjeFgOsqX

Mustafa, A., Kazmi, M., Khan, H. R., Qazi, S. A., & Lodi, S. H. (2022). Towards a carbon neutral and sustainable campus: Case study of NED University of Engineering and Technology. *Sustainability*, *14*(2), Article 794. https://doi.org/10.3390/su14020794

Nguyen, Q., Diaz-Rainey, I., Kitto, A., McNeil, B. I., Pittman, N. A., & Zhang, R. (2023). Scope 3 emissions: Data quality and machine learning prediction accuracy. *PLOS Climate*, *2*(11), Article e0000208. https://doi.org/10.1371/journal.pclm.0000208

Opel, O., Strodel, N., Werner, K. F., Geffken, J., Tribel, A., & Ruck, W. K. L. (2017). Climate-neutral and sustainable campus Leuphana University of Lueneburg. *Energy*, *141*, 2628–2639. https://doi.org/10.1016/j.energy.2017.08.039

Pinuer, F. V., Valenzuela-Fernández, L., Andreu, J. L., & Belbeze, P. L. (2022). La sostenibilidad medioambiental y sus factores en las pymes: Un estudio de casos múltiples en España y Chile [Environmental sustainability and their factors in SMEs: A multiple case study of Spain and Chile. *Mangement Lettrs/ Cuadernos de Gestion*, *22*(1), 35–50. https://doi.org/10.5295/cdg.211370fv

Rehman, A., Ma, H., Ahmad, M. I., Batool, Z., Tillaguango, B., & Oláh, J. (2025). The technology innovation paradox in Asia's leading innovative economies: The importance of renewable energy and green financing. *Technological and Economic Development of Economy*, *31*(6), 1953–1978. https://doi.org/10.3846/tede.2025.23722

Riga Technical University. (2024). *RTU releases first report on CLIMATE neutrality progress, achieving 17% annual reduction in climate impact*. https://www.rtu.lv/en/university/for-mass-media/news/open/rtu-releases-first-report-on-climate-neutrality-progress-achieving-17-annual-reduction-in-climate-impact

Samara, F., Ibrahim, S., Yousuf, M. E., & Armour, R. (2022). Carbon footprint at a United Arab Emirates University: GHG protocol. *Sustainability*, *14*(5), Article 2522. https://doi.org/10.3390/su14052522

Santos, A. N., Brasil, M. V. d. O., Sumiya, L. A., & de Brelaz, G. (2024). Sustainable environmental management in a federal public university from the perspective of the UI GreenMetric. *Journal of Environmental Management & Sustainability*, *13*(1), Article e23013. https://doi.org/10.5585/2024.23013

Sen, G., Chau, H.-W., Tariq, M. A. U. R., Muttil, N., & Ng, A. W. M. (2022). Achieving sustainability and carbon neutrality in higher education institutions: A review. *Sustainability*, *14*(1), Article 222. https://doi.org/10.3390/su14010222

Tallinn University of Technology. (2023). *Green strategy of Tallinn University of Technology 2023–2035*. https://oigusaktid.taltech.ee/wp-content/uploads/2023/07/TT_Rohestrateegia-EN.pdf

Tantekin, A. (2025). Heating degree days (HDD) forecasting and heating degree days factor (HDDF) assessment in selected European countries. *Energy*, *332*, Article 137277. https://doi.org/10.1016/j.energy.2025.137277

Tian, X., Zhou, Y., Morris, B., & You, F. (2022). Sustainable design of Cornell University campus energy systems toward climate neutrality and 100% renewables. *Renewable and Sustainable Energy Reviews*, *161*, Article 112383. https://doi.org/10.1016/j.rser.2022.112383

Townsend, J., & Barrett, J. (2015). Exploring the applications of carbon footprinting towards sustainability at a UK university: Reporting and decision making. *Journal of Cleaner Production*, *107*, 164–176. https://doi.org/10.1016/j.jclepro.2013.11.004

Udas, E., Wölk, M., & Wilmking, M. (2018). The "carbon-neutral university" – a study from Germany. *International Journal of Sustainability in Higher Education*, *19*(1), 130–145. https://doi.org/10.1108/IJSHE-05-2016-0089

University of Greifswald. (n.d.-a). *Climate-neutral campus*. https://www.uni-greifswald.de/en/universitaet/information/aktuelles/klima-und-universitaet-2022/climate-neutral-campus/

University of Greifswald. (n.d.-b). *Sustainable University*. https://www.uni-greifswald.de/en/university/information/current-news/sustainable-university/https://www.uni-greifswald.de/en/university/information/current-news/sustainable-university/%23c2729023

University of Greifswald. (n.d.-c). *The University in numbers 2022*. https://www.uni-greifswald.de/en/university/information/numbers-facts/key-data-and-numbers/the-university-in-numbers-2022/

University of Turku. (n.d.). *Environmental footprint of the University of Turku*. https://www.utu.fi/en/university/sustainability-and-responsibility/environmental-footprint

Veludo, G., Cunha, M., Sá, M. M., & Oliveira-Silva, C. (2021). Offsetting the impact of CO_2 emissions resulting from the transport of Maiêutica's academic campus community. *Sustainability*, *13*(18), Article 10227. https://doi.org/10.3390/su131810227

VILNIUS TECH. (2021). *Tvaraus universiteto vystymosi koncepsija* [Sustainable university development concept]. https://vilniustech.lt/tvarumo-centras/tvarumas-universitete/tvarumo-dokumentai/372107

Wang, J., Zhang, J., Cifuentes-Faura, J., Crenguta Ileana, S., & Zhao, X. (2024). Exploring factors influencing the digital economy: Uncovering the relationship structure to improve sustainability in China. *Technological and Economic Development of Economy*, *30*(2), 441–463. https://doi.org/10.3846/tede.2024.20600

World Business Council for Sustainable Development & World Resources Institute (2004). *The greenhouse gas protocol*: *A corporate accounting and reporting standard* (Revised ed.). https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

Xu, M., Xu, Q., Wei, S., & Cong, L. (2024). The role of organizational resilience in social, economic, environmental and human sustainability: Evidence form Chinese FMCG sector. *Technological and Economic Development of Economy*, *30*(3), 733–752. https://doi.org/10.3846/tede.2024.20476

Yaman, C. (2022). Greenhouse gas management. In The Palgrave handbook of global sustainability (pp. 1–18). Palgrave. https://doi.org/10.1007/978-3-030-38948-2_28-1

Yusoff, S., Abu Bakar, A., Rahmat Fakri, M. F., & Ahmad, A. Z. (2021). Sustainability initiative for a Malaysian university campus: living laboratories and the reduction of greenhouse gas emissions. *Environment, Development and Sustainability*, *23*, 14046–14067. https://doi.org/10.1007/s10668-021-01250-1

Zhang, L., Xu, M., Chen, H., Li, Y., & Chen, S. (2022). Globalization, green economy and environmental challenges: State of the art review for practical implications. *Frontiers in Environmental Science*, *10*, Article 870271. https://doi.org/10.3389/fenvs.2022.870271

Zhang, X., Yao, G., Vishwakarma, S., Dalin, C., Komarek, A. M., Kanter, D. R., Davis, K. F., Pfeifer, K., Zhao, J., Zou, T., D'Odorico, P., Folberth, C., Rodriguez, F. G., Fanzo, J., Rosa, L., Dennison, W., Musumba, M., Heyman, A., & Davidson, E. A. (2021). Quantitative assessment of agricultural sustainability reveals divergent priorities among nations. *One Earth*, *4*(9), 1262–1277. https://doi.org/10.1016/j.oneear.2021.08.015